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Exhaust Emissions from a Stratified Charge Ford Combustion Process (FCP) Engine

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Ann Arbor, MI

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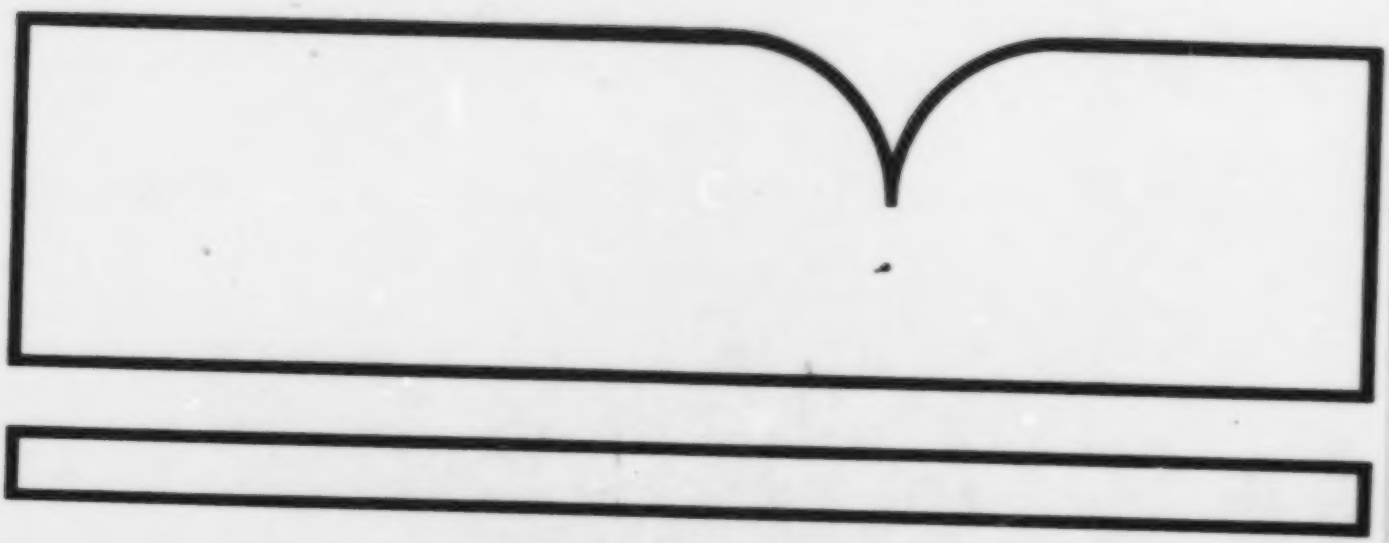

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16. ABSTRACT

The Ford Motor Company, through joint U.S. Army-NAPCA contracts, has produced a "low emission" version of their stratified charge engine. This engine is a modification of the Ford combustion engine tested by NAPCA.

The engine, a modification of the L-141 military engine, was installed in a M-151-1/4 ton Army Jeep similar to the one used in previous tests. The engine was tested both with and without an exhaust catalyst. Unleaded Indolene was used when the exhaust catalyst was in place, and Indolene 30 was used in the other test.

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May 1970

John C. Thomson
Division of Motor Vehicle Pollution Control
National Air Pollution Control Administration
Department of Health, Education, and Welfare

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Subject: FCP Jeep test program results

The Ford Motor Company, through joint U.S. Army-NAPCA contracts, has produced a "low emission" version of their stratified charge engine. This engine is a modification of the Ford combustion engine tested by NAPCA and reported August 6, 1969. A copy of this report is included as Appendix A.

The engine, a modification of the L-141 military engine, was installed in a M-151-1/4 ton Army Jeep similar to the one used in previous tests[1]. The engine was tested both with and without an exhaust catalyst. Unleaded Indolene was used when the exhaust catalyst was in place, and Indolene 30 was used in the other test.

A standard L-141 engine (four cylinder, 3-7/8" bore, 3" stroke, 141.5 CID) was modified by Ford Motor Company to incorporate the required features for operation on their stratified charge combustion process. This system utilizes low pressure (600 psi) cylinder fuel injection with a controlled air swirl in conjunction with spark ignition. The inlet air is throttled to give an air-fuel ratio of 18 to 1. In addition exhaust gas recirculation was added to reduce oxides of nitrogen. A special enrichment system that closes the exhaust gas recirculation valve is used at full throttle.

The following tests were conducted

a. 1968 Federal procedure for exhaust emissions (FTP).

b. 9 cycles of the 7-mode Federal cycle used with constant volume sampling (CVS).

c. Selected hot cycles using the 7-mode Federal cycle.

d. The proposed 1972 LA4-S3 test cycle. (see Table 2)

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[1] See Emissions from Standard M-151 Jeep, National Air Pollution Control Administration, Ypsilanti, Michigan, February 1970.

The Federal procedure data were obtained with NDIR instruments while both NDIR and FID were used with the CVS and 1972 procedure. The Saltzman method was used for determination of oxides of nitrogen.

Dynamometer Results

Mass emissions results for this version of the FCP jeep along with previous data on the "fuel economy" FCP jeep and a standard jeep are shown in Table 1. All tests are 9 cycle repeats of the Federal cycle from a cold start. In all tests run with the catalyst either unleaded Indolene or a Ford supplied fuel with 0.5 mg/gallon lead was used. The test without catalyst was run using Indolene 30.

The results of the dynamometer evaluation, based on mass emissions, clearly show the large reductions in emissions that can be found when using a combination of emission control techniques in conjunction with stratified charge. The use of a catalyst in combination with the stratified charge is relatively new and therefore the engine was not tuned for lowest emissions. Ford believes that further reductions are possible.

The addition of the exhaust catalyst caused an increase in exhaust backpressure. This increased engine loading to the point where full throttle mixture enrichment and closing of the exhaust recirculation valve occured on some tests. To provide more consistant results, the enrichment system was disconnected during the CVS test without the catalyst and during the LA4-S3 test.

Smoke

Due to the short development time preceeding the test, a compromise between power output and smoke level has not been obtained. There was evidence of medium smoke and soot along with some odor. Attempts to measure smoke and odor on this vehicle will be made in the future.

Table 1

Mass Emissions Results (CVS)*

	Standard M-151 Jeep	FCP (old) "best economy"	FCP without Catalyst	FCP with Catalyst
HC (FID) gm/mile	8.0	2.34	0.93	0.58
CO (NDIR) gm/mile	100.9	12.26	9.17	5.60
CO_2 (NDIR) gm/mile	-----	-----	290	420
NO_x (Saltz) gm/mile	4.0	4.02	0.99	0.44

* Constant volume sampling technique using 9 repeats of the 7-mode Federal test cycle with a cold start. Fuel with 0.5 mg/gal TEL used during catalyst test.

Summary of Results

a. The addition of the catalyst to the system showed significant reductions in all pollutant levels.

b. Even without the catalyst the emission performance has been much improved over the "best economy" FCP and a 4 to 10 fold reduction over the standard engine.

c. An increase in exhaust emissions was noticed at Ford, due to improper operation of the enrichment system, and after some tuning by Ford a retest is desirable.

d. No life expectancy or durability data is available on the catalyst.

Table 2

LA4-S3 Cold Test Results

Hydrocarbons	0.70 gpm
Carbon monoxide	2.40 gpm
Oxides of nitrogen	0.50 gpm

This test was run using unleaded Indolene and an exhaust catalyst using the proposed constant volume sampling technique.

Division of Motor Vehicle Pollution Control
Willow Run Airport, Ypsilanti, Michigan 48197

Chief, Control Device Evaluation Section August 6, 1969

Engineer, Control Device Evaluation Section

Determination of Mass Emissions of Experimental Ford Stratified Charge Engine Installed in a M-151 1/4 ton Utility Jeep.

The evaluation of the Ford stratified charge engine, in an Army jeep has been completed. The following emissions tests have been performed.

1. Nine cycle, 8-mode tests according to the proposed 1972 Federal procedure, from hot and cold starts.
2. Constant speed tests using the constant volume sampler.
3. Road emissions using proportional sampler.
4. Qualitative determination of the soot output of the engine.

A summary of the emissions results is included in Table I. During the testing period, the injection timing was changed and "combat" gasoline was used instead of Indolene 30. This was done in an effort to reduce the soot output of the engine. The combat gasoline is very similar to Indolene 30, but has about 10% less aromatics. Aromatics are thought to contribute to soot output. The injection timing was advanced from about 20° to 32°. The 1972 procedure emissions results indicate that these changes caused about 15% to 20% increase in hydrocarbon emissions. In general, the emissions from this engine are low when compared to current (1969) pre-mixed charge engines. A series of tests on approximately 120 1969 American made vehicles using the 1972 procedure showed an average hydrocarbon level for these cars of 4.75 grams/mile the range was 2.80 grams/mile to 7.0 grams/mile. The average CO level was 36.7 grams/mile with a range of 12.0 grams/mile to greater than 60 grams/mile.

Road data was obtained using a proportional sampler, described in the June 1963 Public Health Service paper, "An Auto-Exhaust Proportional Sampler", by R. Smith, A. H. Rose, and R. Kruse. The route is a city-suburban route through Belleville with a route speed close to that of the 9, 8-mode cycle test. This data and the CLA-4 route data on the standard Jeep are only included for general information, since the relationship between the emissions measured on these routes and the 1972 procedure emissions is unknown at this time.

The quantity of soot emitted was evaluated by drawing a sample of the exhaust through a paper filter. These filter papers were then visually compared. Using this technique it was evident that advancing the injection timing reduced the soot level substantially. The less aromatic fuel caused a slight reduction in soot level. It was also noted that there was a sharp drop in the amount of soot when going from 30 mph to 40 mph. This is also apparently related to the injection timing. Using the advanced injection timing and combat gasoline the filter would be as dirty as a very bad pre-mixed charge engined vehicle after a 9 cycle test.

In summary, the stratified charge engined Jeep has lower hydrocarbon and much lower carbon monoxide emissions than current pre-mixed charge engined vehicles. However, it does emit a larger quantity of soot, particularly at low speeds.

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Section

MAC:jeb

TABLE I
Mass Emissions Summary

Nine Cycle 8-mode tests

Cold Start				Hot Start			
FID	NDIR	CO	NOx[1]	FID	NDIR	CO	NOx
	grams/mile				grams/mile		
2.34	1.74	12.26	4.02	2.17	1.50	14.63	
2.32	1.73	14.54	4.30				
2.37	1.77	11.35	3.48				

After Injection Timing Advance
Using Combat Gasoline

3.13	2.22	9.33		2.60	2.00	10.76	2.11
3.00	1.95	12.57		2.63	1.75	9.38	2.02
3.19	2.22	11.42					

Constant Speed Emissions

Speed MPH	FID	NDIR	CO	NOx	
	grams/mile				
22	1.56	1.17	9.20	1.38	Fuel:
30	1.83	1.26	10.58	2.04	Indolene 30
40	1.98	1.49	7.88	3.20	20° Injec-
50	1.67	1.37	7.14	2.89	tion timing

Proportional Sampler Data
Modified Belleville Route

Route Speed MPH	FID	NDIR	CO	NOx	
	grams/mile				
21.5	3.54	2.57	8.73	3.72	Fuel:
23.0	3.95	2.31	8.56		Indolene 30
24.0	3.72	2.51	6.77	2.30	32° Injection timing

CLA-4 Route - Standard Jeep[2]

Cold Start	3.56	63.01	1.68	
Hot Start	2.18	48.49	1.67	

1. NOx data by Saltzman Technique.

2. Data obtained in Cincinnati on 4-22-68.